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REPORT

ON THE

SEWERAGE AND DRAINAGE

OF THE

City of Stillwater, Minnesota.

MADE TO THE

CITY COUNCIL,

BY

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ERRATA.

Page 2, 9th line—Insert *of*; read "are a part *of* and connected with."
Page 4, last line—Omit *or* after the word "joints."
Page 8, 15th line—For surface, read *surfaces*.
Page 10, 22d line—For p. m., read *a. m.*
Page 12, 21st line—For influence, read *influences*.

With the Compliments of
Dr. J. Cunningham.

REPORT

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CITY OF STILLWATER.

To the Hon. City Council of the City of Stillwater:

During the early part of this year I had some correspondence with a member of your board, relative to making surveys and plans to establish a system of drainage and sewerage for your city, which resulted in an invitation to come here early in May last to enter upon the work; and now have to report as follows:

Very soon after my arrival here I learned that there were no sewers, (properly so-called) and very few drains, and that the surface water from about one square mile of steep side hill sandy country, was poured down during heavy showers through a few of the principal streets into the heart of the city; that the sand was carried by the water down the steep grades, until it reached the flat grades of the bottom, where following natural laws the water left it to be

removed by shovels. The central portion of your city just referred to may be compared to an amphitheatre crossed radially by four ravines which gather the water and discharge it into a flat arena of about twenty-five acres.

The chief problem thus submitted to me is to provide ways to carry the water with as little damage as possible to property, into Lake St. Croix. The plans for a system of sewerage are a part and connected with the drainage, so far only as I have deemed it necessary to go to the expense of combining the two.

GENERAL REMARKS WITH REGARD TO SEWERAGE AND DRAINAGE.

In a state of nature the rain-water finds its way to the nearest stream or pond over the surface, and by natural depressions and ravines, the growth of vegetation protecting generally the surfaces from wash; but, when man commences to build, to cut down and to grade streets and lots, the surfaces are exposed and washing away increases. Long lines of streets cross the natural water-courses, the population are supplied with water for domestic use, the wants of civilization cause waste which must be removed, and the streets become the new channels by which both the rain and the waste must be conveyed. Valley-lines cannot always be counted on for lines of drainage, as these pass through private property, and complicated questions of damage will arise between owners of property as soon as the natural condition of things is disturbed.

I extract from Rawlinson:

"Sewering and draining in a rude manner must be as old as the "civilization which associated men in towns. Examples of old "sewers exist in China and in India. Rome and other of the "cities of Italy were sewered, and some of the public buildings "were drained, but we have no evidences that entire cities, includ-

"ing streets and houses, were at any period, Roman or pre-"Roman, fully and completely sewered; as even under the ripest "period of Greek and Roman civilization, the cities which have "presented examples of the most refined architecture could have "been only partially sewered, the *cloaca-maxima* of Rome being "one of the largest examples, and this has been more of a valley-"line culvert, than a useful main sewer. The evidence that "sewers and drains, as we now understand them, did not exist "is that no remains of any such sewers has been found in any "single city of antiquity. The mediæval cities and towns of "Europe knew little of sewers and drains. Land draining and "town sewering may therefore be considered modern."

MODERN SEWERAGE.

The first step towards disposing of human excrement and kitchen waste, seems generally to be by digging holes in the ground , the privy vault or the cesspool. These are first constructed so that the liquid may leach away into the ground, or they are built water tight, with the intention of cleaning them out at intervals, perhaps with an overflow so that the water above a certain level may flow off on the land or to the nearest natural water course. Either plan is bad, as these sooner or later become nuisances, polluting the soil, contaminating the air, generating gasses, which are a fruitful source of typhoid fever, scarlet fever, diptheria or other evils. Sooner or later the necessity is felt for well planned and well constructed sewers, which will remove all house waste capable of being carried by water. A complete system of sewers and drains will not contaminate houses by sewage gasses, but will regularly and easily transmit all waste water and all excreta, hour by hour, and day by day to the outlet.

The first step towards sewerage in most all towns seems to be the building of common square stone drains or box-culverts, laid dry or without mortar. The construction of these is brought about by the

necessity felt for removing storm water without washing street or other surfaces. The term of sewers is misapplied to them, but being the only channels approximating to sewers they are misused for that purpose with bad results, as the water soon finds its way through the loose joints of the stone work, leaving the excreta or kitchen refuse stranded on the rough bottom to putrify and return the poisonous gasses to the nearest house. These drains being built to carry large volumes of storm water, are very unsuitable channels for the conveyance of small volumes of sewage. Their rough walls and bottoms, their uneven, irregular grades, soon become the cause of deposits, obstructions and dams which gradually but surely accumulate until the whole is filled up, and it becomes necessary to clean them out by hand.

Without going into a description of the various and numerous plans which have been proposed and tried for the removal or utilization of town sewage, I will simply state that the system generally in use at the present day is what is known as the "*Water Carriage System*," that is, that the water is used as a medium for conveying away through tight, smooth and well built sewers, all human refuse that is capable of being carried by water flowing with a good current.

SEWERS AND DRAINS.

These terms are very commonly confounded and wrongly used.

Sewers are tight channels for the flow of all sewage or waste from water closets, kitchen sinks, baths, wash houses, factories, or other similar matter, comprehended under the general term of sewage.

Drains are commonly laid with open joints or of

dry masonry, and are intended for the conveyance of surface water, springs or natural water courses.

When it it undertaken to accomplish both the above purposes by one channel, such channel is known as a "*Combined Sewer*," or a "*Combined System*," when applied to a whole district.

The common and most approved practice at the present day is to build "*Combined Sewers*," and thus far nothing has been devised which is considered to be superior to the combined water carriage system for sewerage and drainage of a built up town or city.

SEWERAGE OF STILLWATER.

Partly from motives of economy and partly on account of the very sandy condition of the streets, which sand might choke the sewers, if surface drainage were allowed to enter them, I have not thought it best to provide combined sewers in all your streets, but to plan a system, such, that the city may afford to realize its benefits within a few years time.

Sewers large enough to carry off surface water are an expensive luxury; but were they to be built regardless of cost, and the street surfaces left as they are now, without pavement or macadamizing, they would soon be clogged with the street washings; or were catch basins provided often enough to intercept the washing from the sewers, these would be filled by every heavy rain, and a large force of men would have to be provided to keep them cleaned out.

The total length of sewers provided for in the system proposed is about twenty-three and one-half miles, out of which total about four miles are *combined sewers;* the average estimated cost per foot of the combined sewers is $3.50; the average estimated cost of the small pipe sewers is $1.56 per foot.

I have given considerable thought and study to

decide if it were best to provide a full system of sewer-drains for the whole city, or to economise as far as possible by the use of small pipe sewers, allowing the rain-water to run in the gutters. The chief reasons on which I base my decision to use the small pipes are:

First, That the large sewers would make it rather a necessity to pave the streets, or the sewers would be choked by sand, and that it is not desirable to wait so long as will be necessary for this paving, before having the use of the sewers for domestic purposes.

Second, The streets are not crowded thoroughfares, and surface drainage is practicable.

Third and most potent reason, Is that the interest at six per cent. on the difference of cost, would pay for replacing the pipe sewers with large sewers in about 12 years time; therefore should it be desired at some future day to enjoy the benefits of carrying surface water under ground, it is evident that the money spent for small sewers will not have been wasted.

With these thoughts in mind, I have planned for combined sewers *only* in such districts as I considered them necessary to intercept the floods of surface water, which now pour down upon the lower town, and would recommend that the streets be paved or surfaced where these are built. For the rest of the city I have provided only small pipe sewers, of sufficient capacity for the removal of all liquid refuse from dwellings, including the contents of water closets, kitchen sinks, drainage of cellars, where invaded by springs, also the liquid waste from manufacturing establishments, and all other liquid waste of a city usually carried by sewers, excepting only surface water caused by rainfall.

THE COMBINED SEWERS.

The greatest inconvenience and damage experienced from surface water is caused by the flow from three ravines, the *first*, crossing Pine street near the Court House, thence through the gas works and down Nelson's alley; the *second*, crossing Olive street, near Fourth, and through Third to Chestnut street. The *third*, down the St. Paul road ravine, through lots south of Myrtle, crossing Fourth and Third streets, to the same channel in Chestnut street.

In order to intercept the largest portion of the water shed having outlet, through the above described ravines, I have provided for a combined sewer through Pine, Sixth and Olive streets, with a branch in Oak street, which will intercept the surface water coming from a water shed of about 200 acres, and convey it without inconvenience through a brick main sewer under Pine street to Lake St. Croix.

Another combined main sewer is provided down Spring, Myrtle, Third and Chestnut streets, having an outlet through a tunnel in the sand-rock from Second across a point of the bluff to the Pine street outlet; this will not intercept so large an area as the one first described, but will receive the surface water from about 30 acres of the hill north of St. Paul ravine, of which hill Rice street is near the summit, and also the drainage of about 50 acres lying west of Second street and between Pine street and McKusick's millstream, and the water from St. Paul ravine, about 20 acres which will be taken in at the intersection of Fifth and Myrtle streets, making in all about 100 acres intercepted.

I propose to gather the water in St. Paul ravine and to cause it to deposit its sand by the following arrangement:—For a temporary relief, I would lay a box water-way, open at the top, made of two in. plank, about

two feet square, laid as near the bottom of the ravine as a true grade will admit of; the undulations of the ravine will cause the box to touch the bottom of the ravine at some points, while at other places it will be elevated. At the point of contact I would build small dams of plank, or in some other temporary manner; these will cause basins of still water in which the sand will be deposited, and at overflows provided, the clear water will flow into the box and from thence be discharged into the Myrtle street sewer at the intersection of Fifth street.

No trouble from frost need be apprehended, as the heavy showers occur only during spring or summer; after a time, we may expect these depositing basins to fill up with sand, until their surface reach that of the overflows into the box; when this has been accomplished, the velocity of flow will be much reduced on account of the wide and level surfaces of the ravine bottom, and then the box and dams may be raised so as to cause new settling basins.

Another combined sewer is provided for the future through Hancock St., Sixth avenue, Dubuque St., thence down the slope of the bluff and along Main St. to an outlet into the lake near Messrs. Hersey, Bean & Brown's mill. This will cut off the surface drainage from the territory south of Hancock street, and I think a street should be laid out with a practical grade for its path down the bluff from the intersection of Dubuque and Third avenue to a junction with Main street, as shown on the map.

THE PIPE SEWERS.

It will be noticed by investigating the map of the city which accompanies this report, that the system of sewers is shown by lines in the center of streets, the small circles indicate man-holes or flushing-chambers, the direction of flow may be easily folloewd, the

heavy black lines indicate the outlines of drainage districts, which it is intended to drain by each main sewer, the sizes or interior diameter of each in inches is indicated by small figures.

All other streets, except those above described as having combined sewers, are provided with pipe sewers intended for the removal of sewage only; on these streets the surface-water will have to flow in the gutters. Those streets which are tributary to the combined sewers will be drained off by them. All others will flow by street surfaces or by natural ravines to the lake.

It is designed to make use of the channels of McKusick's ravine, the ravine flowing from Pennock street, by Willard street and the Court House and St. Paul ravine, to lay the outlet sewers for the sewerage of a part of those districts which have their natural drainage through them; the location of these, as well as the location of all other outlets may be seen by referring to the map.

SIZE OF SEWERS AND HOW DETERMINED.

In a primative condition of towns, it is customary to *guess* at the size necessary for bridge openings, or channels to carry the flow of streams, or at best to make them equal in capacity to other openings which have passed the waters of the same stream without causing damage; to be on the safe side and make the drains a little too large is a common error.

SIZE FOR COMBINED SEWERS.

For sewers carrying surface water, the size necessary is such as will carry the maximum amount of water falling on the area drained in any given unit of time; where the surfaces are all covered with houses or pavements a very large proportion of the whole volume finds its way to the sewer, but, when the sur-

faces are in a state of nature, or sandy excavations, a large part is absorbed and finds an underground outlet, commonly known as springs. We have to consider the surfaces of a city as covered surfaces whether they are or not, as they soon may be.

RAINFALL.

To determine the maximum rain-fall or heaviest showers falling in short periods of time, we must have recourse to the records of rain-fall kept in the district, but, as I am not able to obtain any such records that have been kept in Stillwater, I visited St. Paul, where I had access to the records kept by the U. S. signal service corps; and communicated by letter with Mr. Wm. Cheney, of Minneapolis, who kindly furnished me some of the results of his observations at the latter city.

The observations at St. Paul cover a period of 10 years, commencing in 1871. The heaviest showers which have occurred during that time were as follows, viz: *July 2d and 3d, 1879*, in 10 hours and 40 minutes 4.93 inches fell; and between 10 p. m. and 4 a. m. of the same days and part of the same rain, there fell in six hours 3.70 inches, this heavy rain caused great damage to property all through this region, and is the heaviest rain of which I can find any record. *June 4, 1880*, in 2 hours and 25 minutes 1.68 inches fell. Mr. Cheney writes me that the heaviest rainfall in a short period of time of which he has any record was 1.22 inches in 1½ hours.

I am not able to ascertain how much rain fell in any one of these hours, as the rain guage was not measured between 10 p. m. and 4 a. m., but Mr. Cheney's record seems to show that it has not exceeded an inch in any one hour.

In most large cities in this country it is now customary to build the combined sewers of a size that

will carry, when running full, the volume of water coming from an inch of rain falling in one hour, on the area drained by it.

From the verbal accounts of the citizens of Stillwater regarding the immense floods of water flowing down Myrtle and Chestnut street gutters during the heavy summer showers, I was led to believe that it rained harder here than any other spot in the country, but from examination of the above named records, I have concluded that the showers are not so heavy as they are in the East. However, water-spouts may occur anywhere, and they may strike your city once in twenty years, but, it would be folly to build sewers to carry any such torrents, for, even if the expense were not considered, it would not be possible to build a sufficient number of street entrances to get such floods into the sewers.

I have therefore calculated the sizes of all combined sewers to be such as will carry off the water resulting from one inch of rain falling in one hour, on the territory drained by it.

SIZES OF PIPE SEWERS.

We have here to provide for the removal of waste-water and excreta from the houses and factories. I have assumed that each city lot is occupied by a house; that each house will use 300 gallons a day for domestic purposes, and that this volume will flow off in about eight hours, and have therefore increased this so as to allow for 1,000 gallons per day for each lot, and have calculated the size of the pipe so that it will be half full when carrying the whole volume, the other half of the area of the pipe will then be available for draining cellars and for carrying off spring water which it may be necessary to get rid of. As many of the houses occupy several lots, and many lots are vacant, and will be for years to come, this

will allow a margin of area available for leakage of joints by which spring or subsoil water may enter the pipes.

Mr. George E. Waring, Jr., who has recently carried out a successful system of small pipe sewers for the city of Memphis, Tenn., says:

"No sewer should be used of a smaller diameter than six inches, "because it will not be safe to adopt a smaller size than four inch "for house drains, and the sewer must be large enough surely to "remove whatever may be delivered by them; because a smaller pipe "than six inches would be less readily ventilated than is desirable, "and because it is not necessary to adopt a smaller radius than "three inches to secure a cleansing of the channel. No sewer should "be more than six inches in diameter until it and its branches "have accumulated a sufficient flow at the hour of greatest use to "fill their size half full, and because the use of a larger size would be "wasteful and because when a sufficient ventilative capacity is se-"cured, as it is in the use of a six inch pipe, the ventilation be-"comes less complete as the size increases, leaving a larger volume "of *contained air* to be moved by the friction of the current or by "extraneous influence, or to be acted upon by changes of tem-"perature and of volume of flow within the sewer.

"The size should be increased gradually, and only so rapidly as "is made necessary by the filling of the sewer half full at the hour "of the greatest flow."

FLUSHING CHAMBERS.

It would not be practicable to use these small pipe sewers, not receiving storm water, without the aid of suitable flushing tanks. At the head of each sewer and of each branch of a sewer, there should be built a flush tank, having a capacity of about 120 gallons. This tank should be built of water tight mason work, under the surface of the ground, but above the level of the head of the sewer. It should be supplied by a constant stream of water from the public water supply, barely sufficient to fill it once in twelve to twenty-four hours. It should be furnished with an

automatic siphon, which, when the tank is filled to the top of its outlet pipe, will discharge the whole amount of water in the tank in about forty seconds, which will rush down the sewer with a velocity of flow sufficient to carry before it every substance, of whatever character, the four inch house branches may have been capable of admitting. Aside from this assuring of the removal of obstructions before they can accumulate to a dangerous extent, the use of the flush tank has the further very important effect of carrying forward to the outlet at least once in twenty-four hours all of the organic matter which, if allowed to remain a longer time would enter into a dangerous decomposition, for, even in a six inch pipe there is a tendency to deposit fæcal matter and other solid substances toward the upper end of the sewers, where the regular flow has not yet accumulated sufficient volume to sweep them forward. In the large sewers of combined systems these accumulations remain, producing the sewer gas of which we hear so much, until the water of a storm sweeps them away.

SELF CLEANSING SEWERS.

I make the following extracts from Baldwin Latham's excellent work on sewerage.

"The early sewer works in this country were generally put into "the hands of most unskillful workmen. Little or no attention was "paid to the proper construction of drains or sewers; in fact it ap-"pears that the fastidious generations of the past looked upon con-"structions that had to do with the removal of those waste matters, "which have to be dealt with in every house and in every town, as "too disgusting in their nature to be mentioned in the ears of re-"fined society. The frightful consequences arising from this ut-"ter disregard of these very necessary matters became the means in "a great measure of awakening attention, and scientific inquiry "into the principles which should regulate the construction of sew-"ers. So well is the importance of securing perfect works of sew-"erage now understood, that it has become a proverbial saying

"that "a man should look to his drains before he furnishes his "drawing room." The early sewers executed in this country have "been called "sewers of deposit;" in fact, at one period it seems "to have been a recognized feature that all sewers must sooner or "later choke from the accumulation of deposit, therefore certain "rules and regulations were laid down for their construction, with "a view to make the sewers of such a size as should be convenient "for the purpose of sending men into them to cleanse them when "they became choked.

"Those of two feet diameter were considered sufficient for men "to crawl into in order to cleanse them; when they were from three feet to three feet six inches, vertical dimensions, men could crouch "in them; when they were from four feet to four feet six inches "men could move in a stooping position, and they were required to "be made six feet in height, in order that men could stand in an "upright position; when constructing sewers on these principles, it "was conceded that the larger they were made the better they "were, for it was shown that if sewers were made sufficiently high "for men to walk through them, a man was able to remove in the "course of a few hours, from a choked sewer, as much matter as "he would in as many days from a sewer of smaller dimensions. "These bad practices are now nearly at an end, and there is no "more necessity of sending men into sewers to carry out such dis-"gusting operations, than there is to send boys up chimneys to "sweep them. The great fault is the early sewer works arose from "the fact that the size, form, mode of construction, or mate-"rials adopted were not in accordance with the work the sewers "had to perform."

They were built square, in section, or with flat bottoms, or with rough stones with open joints. The streams of sewage flowing through the sewers was often very small in proportion to the size of the sewer, and, when spread over a large flat surface, its velocity was so much impeded by the frictional resistance of the bed, and the angles of the channel, that the matters in suspension in the water were deposited, or the water leaked away through the open joints, leaving the solid matter stranded, until, at length the sewers became completely choked, and then com-

menced those disgusting operations of sending men into them to remove the obstructions.

It has since been amply demonstrated, from the results gained by experience in the management and working of sewers, that by so proportioning the size, form, and inclination of a sewer to the volume of sewage it has to carry, it may be made self cleansing.

VELOCITY OF FLOW TO BE MAINTAINED.

In order to prevent deposits in sewers, it is necessary to provide a certain velocity in the flow of sewage, which must be secured throughout the whole system of sewers, and such velocity must be sufficient to prevent the subsidence from the liquid of any matters in suspension, and also to move along the bed of the channel any solid deposit.

EXPERIMENTS.

Numerous experiments have been made, at various times, by different individuals, as to the effect of currents of water in moving matter along variously formed channels, and from these experiments certain rules have been laid down for the guidance of the engineer when constructing works of sewerage.

Mr. Beardmore, in his extremely reliable hydraulic tables, gives the velocity which should be maintained in sewers at 150 feet per minute. Mr. J. Phillips, who had had considerable experience in the working of sewers in London, states that a velocity of two and one-half feet per second, will prevent deposit. Professor Rankine says that the velocity in sewers should not be less than one foot per second, or more than four and one-half feet per second. House drains, he says, should have a velocity of four and one-half feet per second.

M. Dubuat gives the velocity necessary to remove certain solid substances as under:

	Ft.	In	Per Sec.	
River mud, semi-fluid	0	3	"	"
Brown pottery clay	0	3¼	"	"
Common clay	0	6	"	"
Yellow sand, loamy	0	8½	"	"
Common river sand	1	0	"	"
Gravel, size small seed	0	4½	"	"
Gravel, size of peas	0	7⅛	"	"
Gravel, size of beans	1	0½	"	"
Coarse ballast	2	0	"	"
Sea shingle, about 1 inch in diameter	2	2	"	"
Large shingle	3	0	"	"
Angular shingle, size of hen's eggs	3	3	"	"
Broken stones	4	0	"	"
Broken agglomerated, or schistose rocks	4	4	"	"
Rock wich distinct layers	6	0	"	"
Hard rocks	10	0	"	"

Experiments made by J. E. Blackwell, C. E., for the government referees in the plan of the main drainage of London, show very clearly the effect of currents in removing substances of different specific gravities. Coal of a specific gravity of 1.26, commenced to move in a current of from 1.25 to 1.50 feet per second. A second sample of coal of specific gravity, 1.33 did not commence to move until the velocity was 1.50 to 1.75 feet per second; a brick-bat of specific gravity 2.0, chalk of specific gravity 2.05, required a velocity of 1.75 to two feet per second to start them. Oolitic stone, specific gravity 2.17; brickbat 2.12, chalk, specific gravity 2.00, broken granite, specific gravity 2.66, required a velocity of 2.0 to 2.25 feet per second to start them. Chalk specific gravity 2.17; brick-bats specific gravity 2.18; lime stone specific gravity 1.46, required a velocity of from 2.25 to 2.50 feet per second to start them. Oolite stone, speific gravity 2.32, flints, specific gravity 2.66,

lime stone specific gravity 3.00, required a velocity of 2.50 to 2.75 to start them.

It was shown in these experiments that after the start of the material with the current, in no case did the materials to be transported travel at the same rate as the stream, but in every case their progress was considerably less, as a rule often more than 50 per cent. less than the velocity of the current.

Experience has shown that in order to prevent deposit in small sewers or drains, such as those of six inch and nine inch diameter, a velocity of not less than three feet per second should be produced. Sewers from 12 to 24 inches diameter should have a velocity of not less than two and one-half feet per second and in sewers of larger dimensions, in no case should the velocity be less than two feet per second.

In order to maintain these velocities in sewers it is absolutely requisite that a certain rate of inclination should be secured; thus small sewers will require a greater rate of fall than large sewers, and large sewers, on the other hand, must have provided a much larger volume of fluid, so that the proper velocity through them may be maintained.

APPLICATION TO STILLWATER.

I have endeavored to carry out the above principles in adjusting the size and inclinations of the sewers for Stillwater as far as practicable, but, the small pipes at the head of some districts where the ground is flat have a little less than the desired inclination, these, however, having the aid of flushing tanks. I do not anticipate that any inconvenience will be experienced on account of insufficient flow, as flushing tanks at the head of each sewer like those described in a previous article, will more than compensate for the deficiency of inclination.

The trouble that is experienced on account of the deposit of sand in the box drains now existing in Myr-

tle and Chestnut streets, and which is due to the form and size of channel, roughness of surfaces, unequal grades, sharp angles and other reasons fully explained in the preceding pages, need not I think be anticipated to occur when the brick sewers shall have been built to carry off the same water, as in these the section of channel will be uniform, the surfaces smooth curves easy, grades regular, and it may be presumed that a uniform velocity of flow will be maintained, sufficient to carry with it all the sand and small stones that may be washed down from the ravines, or from the street surfaces, and that they will not be dropped by it until the final discharge into Lake St. Croix.

Table showing the proper inclination of circular sewers of various diameters, when running full or half full and the resulting velocities, according to Latham's tables.

Diameter in inches.	Inclination.	Velocity in ft. per second.
4	1 in 53	4 feet
6	1 in 137	3 "
8	1 in 183	3 "
9	1 in 206	3 "
10	1 in 229	3 "
12	1 in 275	3 "
15	1 in 344	3 "
18	1 in 412	3 "
20	1 in 458	3 "
24	1 in 550	3 "
30	1 in 687	3 "
36	1 in 825	3 "

But, as the condition of sewers under ordinary circumstances is, that a very small stream of house sewage only covers a few inches of the bottom, and occupies only a fractional part of its sectional area, the velocity of flow from the same sized sewer being proportional to its depth, and the depth never being the same, renders it impracticable to assume that the sewers are running half full, unless we aid the volume by flushing.

Mr. Wicksteed, an experienced hydraulic engineer gives the following table of the least velocities and grades or falls to be given to drain pipes and sewers in cities, in order that they may under *ordinary circumstances* keep themselves clean, or free from deposit:

Diameter in Inches.	Velocity in Feet per minute.	Grade one in	Grade in feet per mile.
6	220	65	81 2
8	220	87	60 7
10	210	119	44 4
12	190	175	30 2
15	180	244	21 6
18	180	294	18 0
24	180	392	13 5
30	180	490	10 8
36	180	588	9 0
42	180	686	7 7
48	180	784	6 8
60	180	980	5 4

Fig. 1.

A B, Flow of storm water from forty-three acres of paved and covered surface.

C D, Ordinary flow of the sewerage from 1,200 houses.

EXPERIMENTS MADE TO DETERMINE THE AMOUNT OF SEWAGE FROM 1,200 HOUSES.

"In this sewer, (shown in the accompanying figure 1) which has a flat segmental bottom, three feet wide, a sectional area of 15 feet, and an average fall of one in 118, the deposit from the 1,200 houses readily accumulates at the rate of 6,000 cubic feet per month. But a pipe of 15 inches diameter, placed along the bottom of this sewer, with a somewhat less inclination (1 in 155) kept it perfectly clear of deposit. The average flow without rainfall, was about fifty-one gallons per house per diem. The absolute drainage apart from the rain water from all the 1,200 houses would have passed through a five inch tube, (of the relative size of the smaller one, shown within the 15 inch tubular pipe placed along the bottom of the brick sewer), or not one third the area of the minimum sized drain which had, up to the time of the investigation, been declared and enacted in the metropolitan building act, to be necessary for a single house; namely, one of not less than nine inches in diameter."—Extract from an English Parliamentary report.

I have quoted the above experiment, as many will think that a six inch main or street sewer, is too small, but, it must be born in mind that such mains are destined for sewage only and that flushing will exert a more powerful effect on a six inch pipe than it would on one of any greater diameter.

BRICK SEWERS.

For sizes greater than fifteen inches diameter, I would recommend generally that the sewers be built of well shaped hard burned brick laid in hydraulic cement mortar, (unless there be some good reason such as quicksand, powerful springs or bad ground, which makes it impracticable to lay brick in cement, in which case it may be advisable to use pipe of greater diameter than 15 inches) *generally* to be of one ring or thickness of brick for all sizes under three feet, and of two rings or eight inches brick arch, if of three feet diameter or greater. Form of section to be egg-shaped, with the small end down. Suitable foundations should be provided according to the nature of the ground, but, for convenience and accuracy of

laying in ordinary sand or gravel, and to give a more uniform bearing while the mortar is green, the invert should be laid on narrow strips of plank, laid lengthwise, and carried a short distance up each side. The hardest and smoothest bricks should always be selected for the invert or bottom of the sewer.

Fig 2.

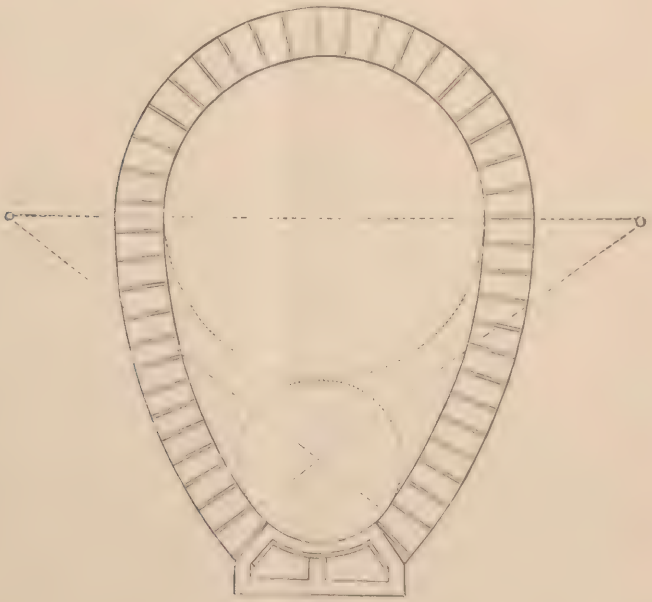
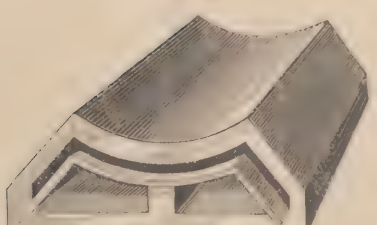


Fig. 3.



INVERT BLOCK.

In cases where the bottom of the sewer trench is in very wet or springy ground, or where the inclination

and velocity is very great I would use "Invert blocks" of stone ware, or fire clay, glazed upon the invert face. These invert blocks greatly facilitate the construction of the sewer. See diagrams Fig. 2 and Fig. 3.

Great care should be taken in packing gravel or sand or other suitable material, under and at the sides of the inverts so as to leave no void spaces for settlement, and to fill on both sides of the arch uniformly, and ram the earth well over the arch, which ought to be entirely covered before drawing the centres.

PIPE SEWERS.

One of the most important questions to be settled in the drainage of a city is the kind of pipe which it is best to use, as the length of pipe-sewers so far exceeds that of brick.

GLAZED PIPE.

Experience has shown us that burnt clay and glass are *two of the most indestructable* materials that can be fashioned by man, as utensils of both substances have been found in perfect state of preservation in the ruins of the most ancient civilization. I do not think it requires much evidence to prove that if these pipes are made of good fire clay of sufficient thickness and well burned, and if their surfaces are protected by proper glazing, if true of form and with smooth surfaces that they are the best pipe known for the purpose; the glazing, if put on properly, is a true glass and will resist the action of even nitric or sulphuric acid.

The rate or velocity of flow through smooth glazed pipes has been found by Mr. Roe's experiments in London to be very much greater than in brick sewers.

The glazed pipe now mostly in use is better suited to the purpose than pottery pipe, and is in fact glazed

fire-brick, less brittle than the stone ware and will admit of being cut to suit required lengths of drains. Formerly the strength and durability of this pipe was questioned, because those first used for drainage were quite thin, frequently but half an inch thick for pipes of twelve inches in diameter and over, and of a light porous body, similar to drain tiles, and without glaze, called red earthen-ware pipes.

The pipes now made at Akron, Ohio, at Jolliet, Ill., Cuyahoga Falls, Ohio, Portland, Maine, and some other places, are thick and strong vitrified stone ware, or fire clay with a silicate glaze, are not liable to fracture in the handling, and are strong enough to resist great pressure of earth, as has been proved beyond a question by the careful tests made at Brooklyn, N. Y., at Boston, Mass., and at Chicago, Ill. I would recommend that such pipe be used in Stillwater, with strict requirements that they shall be smooth inside and true to form and required diameter.

The joints should be made with sleeves or rings rather than with sockets and spigots, as the former may be laid more true to line and may be more carefully jointed with cement, than the latter.

CEMENT DRAIN PIPE.

Pipe made of sand and hydraulic cement and moulded into short lengths have been used to some extent in this country, but less so than formerly. Their use has been discontinued in Boston, New York, Chicago, Cincinnati and most large cities. I have found generally that where they are used it is because some political influence is brought to bear in their favor upon those having the power of selection. The great objection to their use is the uncertainty of their quality, because poor cement may be used, or the materials be improperly worked, or both. Such pipes cannot be depended upon to withstand pressure in the

trenches, and they are very liable to soften and disintegrate by the action of the acid in the sewage. They are heavier to handle and not so smooth as glazed pipe. It is claimed for them that they are somewhat cheaper, those pipes of less than 12 inches diameter costing somewhat less than glazed pipe, but even this is a matter of doubt, when we consider that they cost more to handle, and that owing to increased roughness a larger diameter would be required to do the same work

INLETS AND BRANCHES.

When building a sewer, whether of brick or pipe, care should be taken to build in all pipe-branches or house connections, which may be wanted, to avoid breaking open the sewer, and of these a record should be kept, and their position and size located on the sewer plans. All branches should enter the main with a curved junction or slant to discharge in the direction of the flow, as right-angle junctions will cause deposits and impede the flow in the sewers.

MANHOLES.

Manholes for inspection, ventilation, and to avoid digging up streets should be built at every street intersection and at most changes of grade or direction, generally not over 300 feet apart. If the sewers are laid true to line and grade, and the manholes sufficiently near, a lantern held in one manhole may be seen from the next, which, if not visible, is an evidence of an obstruction, which may then be removed by flushing from the street hydrant, by jointed rods, or by a drag chain. Manholes should be built of brick, of sufficient size for convenient entrance, with steps to descend by, provided with strong cast iron ventilating covers; each cover having a pan hung under it to catch the sand that might otherewis fall in and obstruct the sewer.

LAMP-HOLES.

As far as practicable, all small sewers will be laid in straght lines, both for grade and direction, and at all changes of grade or direction, where there is not a man-hole, a lamp hole built of brick or pipe, just large enough to let down a lantern will be placed. The junction curves being formed of cement in the bottom and open part of the man-hole, will give access to the tangent point for holding the lantern.

CATCH-BASINS.

In those streets for which combined sewers are proposed to take surface water, the inlets for this will be under the edge of the side-walk, either at the sides or street-corners, to be located at intervals of from 200 to 400 feet, according to circumstances. The water falls through these openings into catch-basins built of brick; from a point about 5 feet below the surface, (on account of frost), a pipe leads to the sewer. Over the mouth of this pipe, but not closing it, hangs an iron hood. The lower part of this hood dips into the water, which stands at the level of the bottom of the pipe-mouth, forming a trap to prevent the escape of sewer gas.

In your streets, until they are paved, quantities of sand and other substances will be washed into these receptacles, which will prevent such obstructions from being carried into the sewers. A force of men must be kept to clean them out after storms, or they will be soon choked. The basins are entered for this purpose through openings with iron covers placed in the edge of the sidewalk.

VENTILATION.

It is not safe to build sewers without provision for ventilation. The simplest method is to provide perforated iron covers for all street man-holes; these

should be frequent, that there may be unceasing motion and interchange between the outer air and the inner sewer air. In unventilated sewers the gas soon becomes deadly, while in fully ventilated sewers, the air is purer than that of many a crowded public room.

With gradients as steep as those of many streets in Stillwater, there is a constant tendency for the sewer gasses to rise and accumulate in the upper levels. This should be provided against by building tumbling-bays in the man-holes, with flap-valves closing against the upper sewer end, as shown by drawing. The upper or dead-ends will be provided with ventilation through perforated covers of the flushing chambers.

SEWER OUTLETS AND DISPOSAL OF SEWAGE.

Lake St. Croix is an enlargement of the river of same name having a width of about 2,000 feet at high water. The water shed of the river above Stillwater is about 6,600 square miles, sufficient to furnish a volume of water which should swallow up the sewage of Stillwater without inconvenience to anybody. But, to secure this end, the discharge should be made into deep water, as near the channel or thread of the current as is practicable. Opposite the north end of the city the channel is along the Wisconsin shore, but from the new elevator to Hersey, Bean & Brown's saw mill it is near the west bank of the lake; in fact, opposite the end of Pine street, produced. I find, June 10th, that the water was 29 feet deep at a point 50 feet from the shore; the current is sluggish, but, it is generally setting one way and all the most objectionable matter contained in the sewage would be carried along by it. I have therefore adopted this point, off from Main and opposite Pine street as an outlet for the sewage of all the principal part of the

city. It is necessary, however, that the sewer outlet should be built out into the deep water of the channel, so that the offensive matter may be carried by the current instead of being stranded on the river bank, to decompose and pollute the neighborhood.

I would make the level of the bottom of this outlet about the same as that of low water in the lake in order to receive the drainage of the low part of Main street. (There is a difference of 20 feet between high and low water marks of the lake.) The end of the sewer should be so protected by a flap-valve as to prevent the air from blowing up the sewer. The same valve or gate may be so arranged as to exclude the water, if it be found necessary to pump out this end of the sewer for cleaning or repairs. The man-hole on Main street, 140 feet from the end will serve as a vent for the confined air and for ventilation. There will be a flap-valve in this man-hole to shut off the high water when it becomes necessary to resort to pumping out the Main street sewer.

HOUSE DRAINS.

The safety and comfort of the inhabitants will depend more upon the proper arrangement and perfect construction of house drains, water-closets and sinks than upon the main sewers; but in many cases local authorities after having carefully constructed main sewers have paid little or no attention to house drains, the results being great discomfort, injury to health and discontent.

The proper juncture of house drains with sewers should be imperative, and house drains should always be executed in accordance with a sanctioned plan, the local authority insisting, as far as practicable, upon every house drain being designed, constructed, and carried to the main sewers under the supervision of their city engineer, who may be supposed to understand such construction.

The house drain should have an inclination not less than 1 in 60, should never be joined to a sewer direct, so as to form a continuous flue by which gasses may flow into the house. There must be a break in the drain and means for ventilation so as not to cause nuisance. Ventilation of sewers and drains is too often neglected; it must be insisted upon. House branches should not exceed four inches in diameter, as many of the main sewers are but six inches, and if the branches are as large or larger than the mains, obstructions will be introduced that will choke the mains. I have already presented a draught for an ordinance to your body intended to cover this point, and now to bring it more clearly before the people, I give with this report a sketch intending to illustrate a good method for connecting house drains with the sewer.

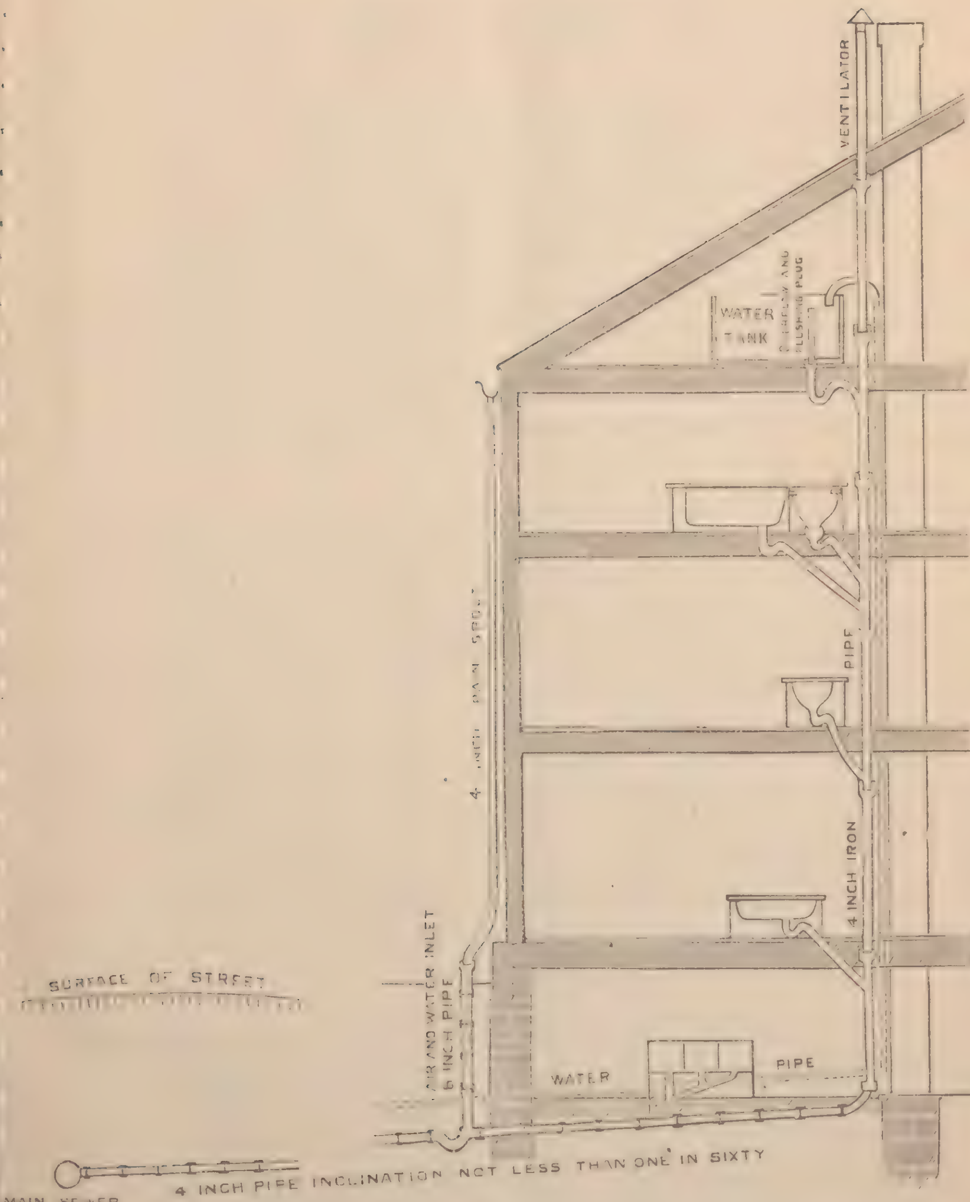


DIAGRAM SHOWING HOUSE DRAINAGE AND VENTILATION OF DRAINS.

EXPLANATION TO DIAGRAM, SHOWING HOUSE-DRAINAGE AND VENTILATION OF DRAINS.

It will be noticed that the ventilator pipe outside of the house wall, is an inlet pipe for air and for the rain water from the house roof. It is made 6 inches diameter to leave an air space and cut-off or separation from the sewer. It is left a foot above the surface of ground to prevent obstructions from getting into the drain. The 4-inch iron drain pipe being continued vertically to the top of the house, there will be a constant current of air flowing upward through it. No confined sewer gas can ever be forced out through the traps, for, though everything is double trapped, there is an air vent always open. The rain spout will help to keep the drains clean, and the water tank in the attic may be used as a flushing tank to empty suddenly, by pulling out the hollow 4 inch overflow plug.

SAND-ROCK SEWERS.

For some of the streets along the top of the bluff near the lake front, where the hard lime stone rock is at or near the surface, and this is underlaid by a strata of soft sand stone, I have found that it will be cheaper to build the sewers by a tunnel through the sand stone, rather than by an open trench in the hard rock, and to make the house connections by a drill hole between each two houses, communicating with the street sewer by a branch tunnel, also in the sand rock, after the manner that this is done at St. Paul. The Second street and Pine street tunnels I anticipate will not be found difficult of execution.

SURFACE DRAINAGF.

For a large portion of the city the surface water must find its way to the lake by the street gutters, and these, as well as the street surfaces, in order to carry off the water without inconvenience, must be constructed in such form and manner as has been found by the longer experience of other hilly cities best suited to the work.

The first principle to follow, is to make the street surface lower than the sidewalk. An upright curbstone at the edge of sidewalk will form a gutter eight or ten inches deep. The street surface should be slightly crowned, say five inches in the centre, the sidewalk should have an inclination toward the gutter of about one-half inch to the foot, and so far as practicable I would make both sides of the street the same level. If on a side hill the difference of level can be arranged by a high sidewalk, and a wall or terraces at the front of the lot. The steep streets should be paved or surfaced as soon as practicable, but, if not practicable to pave way across, then pave a gutter, following the above form of section.

Long lines of drainage accumulating the watershed of a large territory should be avoided; to prevent this, turn the water off frequently by short lines to the lake. Taking Third street as an example, I would turn the drainage from the north end off at Linden and Mulberry streets and Second street below Mulberry into the mill streams so that it may not accumulate to a flood in Myrtle street. The same plan can be adopted in other parts of the city, where there are no combined sewers, by making use of the natural ravines, with wooden boxes or other suitable protection against wash. Third street south of Mulberry and Second streets, south of mill stream, will be drained off by the combined sewers in those streets, through the tunnel from Second street to Pine street outlet, and the tunnel sewer should eventually also carry off the surface water falling in the area of original town included between Myrtle, Pine, Second and Sixth streets. The ravine running by Mrs. Tepass' brewery, draining about 80 acres, may be relieved by excavating a tunnel in the sand-stone through Broadway to connect with the Pine street tunnel. The water may be conducted to

this tunnel by a shaft from above located at the junction of Willard street and Sixth avenue. This would then also receive the sewerage of a small district shown on the general map.

Where there are combined sewers, like those designed for Pine, Sixth and Olive streets, these will take the surface water of the territory tributary to them; where no combined sewers are provided, the mill stream and other ravines will for a time longer take the surface drainage as they always have done.

STREET GRADES AND INTERSECTIONS.

I have caused to be made new profiles of all the streets. On these, the grades established by city ordinances are marked with black lines. Those previously drawn on profiles and that have been used to some extent, are marked with blue lines; and where I have found it necessary to make changes on account of drainage, I have drawn a red line; (the top and bottom of the sewers are also shown in red). The grades shown are only those of the centre line of the street. The adjustment of side grades and intersections must be considered and studied for each case, when it becomes necessary to do the grading. I can only suggest general principles which should govern in this matter, thus:

Where a steep street *crosses* one that is nearly on a contour line, I would reduce the grade of the steep street at the intersection, so that it shall be a mean between a level line and the steep grade. This will make an increased fall in the lower gutters, commencing a short way back from the corners. The grades on the two lower corner sidewalks will have an increased pitch to accommodate themselves to this depression, but, these should be kept high enough, so that the curbstone will form a barrier to keep the water from invading the walk. The upper gutters

may then drain whichever way is found desirable, but the sidewalks should, in all cases, be built high enough to keep them dry.

In a case where a street built with a level cross-section on a side hill *intersects* a street with a uniform grade down the hill, the street which is tributary to the down hill street will gradually change (as a warped surface) from level across, until it conforms to the grade of the steeper street. The distance back from the junction where it commences to be warped will depend upon the grade of the steeper street. As far as practicable I would advise making the cross-sections of the streets level; that is to say, both gutters the same level and the street crowning uniformly from a level line, the difference of level in the two sides being made up by walls or terraces at the front of lots. It is not desirable to have the streets graded so that the water will run to the down hill side, or onto the sidewalk as it does now. (See drawing of cross-section of steep streets).

PUMPING MAIN STREET SEWAGE.

As it was decided by your board not to raise the grade of Main street sufficient for its natural drainage at all times, it will be necessary to provide means for shutting off a portion of Main street and its connections from the other system; to so isolate it that the street sewer may be pumped out during high water in the lake. I have planned to have Mulberry street sewer connect with Main street, in order to furnish sufficient volume of water to fill a large pipe and allow of a flatter grade than would otherwise be allowable for the natural requirements of Main street if left entirely without aid from the drainage of other territory; but, when it becomes necessary to pump out the Main street sewer, owing to high water in the lake, then the gate which is shown on the plans, at

Mulberry and Second must be closed, the main outlet remaining open south through Second street.

PUMP IN NELSON STREET.

A small territory of about 1,800 feet long by 600 feet wide, being the Main street and most valuable part of the city will then be dependent for its drainage upon the pump which I propose to locate at the intersection of Nelson street and Stimpson's alley in a small pump-well built of brick for the purpose. The sewage will be conducted to this well by a six inch drain pipe from Main street, having an inclination *to* the well. Another pipe will be laid in the same trench having an inclination *from* Stimpson's alley toward Main street for the natural drainage during ordinary low water, but, during high water the lower pipe will drain the Main street sewer back eastward towards this pump-well

I calculate the quantity of sewage to be pumped in the following manner: The number of lots to be drained between Mulberry street and the Pine street outlet would be about 119; allowing for 1,000 gallons per day from each lot, of drainage, and that this would flow off in eight hours; the quantity resulting must be 249 gallons per minute. If allowance is made for draining cellars during high water, under the supposition that an effort is made to stop out the leakage by concrete floors and water-tight masonry from these cellars then we may figure for 1,000 gallons from the cellar of each lot flowing off in 24 hours, which will give 83 gallons per minute; then there is to be pumped 249+83=332 gallons and this to be raised ten feet; then 332x10x8.35=27,722 foot lbs., or less than one horse power. There is 150 feet head at this point from the public water supply; a pipe one and one-half inches in diameter furnishing water under this head to a six inch turbine wheel or one of Tuerk &

Johnson's water motors would give more than the necessary power, but to allow for friction and emergencies I would take the water from a two inch pipe to run a water motor and this to be the means of driving a small centrifugal pump, which shall discharge the sewage and water directly into Lake St. Croix, at the foot of Nelson street.

GENERAL RECOMMENDATIONS.

Everything relating to sewers and house connections must be under the charge of *one* competent and responsible head; their construction and the choice of materials of which to build them, their location, the number and position of man-holes and catch-basins, and all details. The same person should keep the record of every sewer and drain laid, and locate its position on the recording plans, and also record the assessments in the same plans. If this method is followed, there need never any annoyance arise from not knowing where the sewer is, nor from any conflict of authorities. The City Council will naturally determine what work shall be done and what money spent, but, for the good of the city, it may be hoped that they will leave the details of construction to one person skilled in the special work assigned to him.

I have already alluded to the necessity for raising the grade of Main street (original town) in order to secure good drainage; which you have decided not to undertake on account of the expense and difficulties it presents.

I would now call your attention to the necessity of re-locating the lines of Main street from the Penitentiary to the northern limit of the city. The St. Paul and Duluth railroad has taken possession of a considerable part of this street; the balance is either crowded down the hill or against the bluff. The old line was very crooked, its natural grade very undula-

ting. It is altogether unsuitable for travel or for drainage. The present traveled road is principally over private property; the line and grade of the railroad would make an excellent line for a street, and I therefore recommend that a new location be secured as early as possible on the west side of the railroad location, parallel with and having the same elevation and grade as the railroad. This would improve the value of the lots fronting the street, would facilitate the transaction of all kinds of business, and make a good finish to what is now in a chaotic state.

I would also recommend that a more definite location be made for the southern end of Main street, from Locust to Orleans streets, which should have a uniform width, following the west side of the location of the other railroad, as the conditions of this are very similar to those already described of the north end.

A street should also be laid out along the slope of the bluff from the intersection of Dubuque and Third avenue, to intersect with Main street near Messrs. Hersey, Bean & Brown's saw mill, a distance of about 850 feet. This will be needed in the future as a channel for the main-drainage, and will form a means of access that will be required between the business front of the city and the very desirable building sites on that part of the South hill

When it becomes necessary to grade a street, it is not practicable that all abuttors shall be equally benefitted; but, private interest must give way for the public good. A grade should be adopted with careful study and deliberation, but after being adopted, it should not be fudged to suit the wishes of the less fortunate. These plead in piteous tones that they are ruined, and are likely to be the first to bring suit against the city for damages, which, indirectly,

may have been caused by fudging this grade to suit them.

I would here remind you that no system of drains or sewers can be constructed by human agency that, after completion, will not need careful attention, and any one expecting such perfection will be as disappointed with the results as the constructor of machines of perpetual motion.

Eternal vigilance is the price of liberty, just as much in the hidden and artificial channels for drainage and sewerage as in matters politic.

DESCRIPTION OF PLANS.

I have made use of one of Mr. Shepard's lithographed maps of the city to show the lines, sizes and directions of all the sewers forming the system. This also shows by heavy black lines the outlines of the several drainage districts, and by red figures forms an index to the detailed streets or recording plans. A reduced lithographed copy is bound with this report.

I also leave with you a profile of each street showing the grade of centre of street, and the sewers as proposed, with their sizes, depths and rates of fall.

Also one or more sheets (as a sample) of the Recording plans. These are each two by three feet, mounted on cloth, to be bound together or kept in a portfolio, for reference by their number. They will show every lot in the city, with owners name, and all dimensions of blocks and lots; they will serve as a record for the location of all sewers with their branches, house inlets and other appurtenances, and also as a record for the various improvement assessments charged to and paid by each lot, and may be made the official plats of the city.

Also the following will be made, viz:

Plan for the construction of Pine street outlet.

General plan for a sewer manhole.

General plan for a sewer catch basin.

General plan for a lamp hole.

General plan for a flushing tank.

Section of tunnel and sewer in sand rock.

Sections of all the brick sewers.

Plan of junction of Third and Chestnut streets sewers.

Plan of junction of Second and Chestnut streets sewers.

Plan of junction of Myrtle and Third streets sewers.

Plan of valve chamber and tumble bay.

Junction of Court House Ravine and Pine street sewers.

General cross section for a street.

Nelson street pump well and some others.

CONCLUSION.

I make you my report before the completion of the plans and profiles herein mentioned, that you may have time to consider and take action upon the subjects with the explanations that I have offered in it, while I am yet with you, and because the additional work that you have given me of establishing and adjusting all the street grades, together with the work of the office of the City Engineer, might be the cause of an undesirable delay before you would hear from me.

Appended you will find an approximate estimate of the cost, with the length and sizes of the sewers in each street of your city for which I have thought it necessary to provide sewerage.

Acknowledging valuable assistance from Mr. Elbert Nexsen, and with thanks to the City Council for their courtesy,

This report is respectfully submitted.

D. W. CUNNINGHAM,

Engineer.

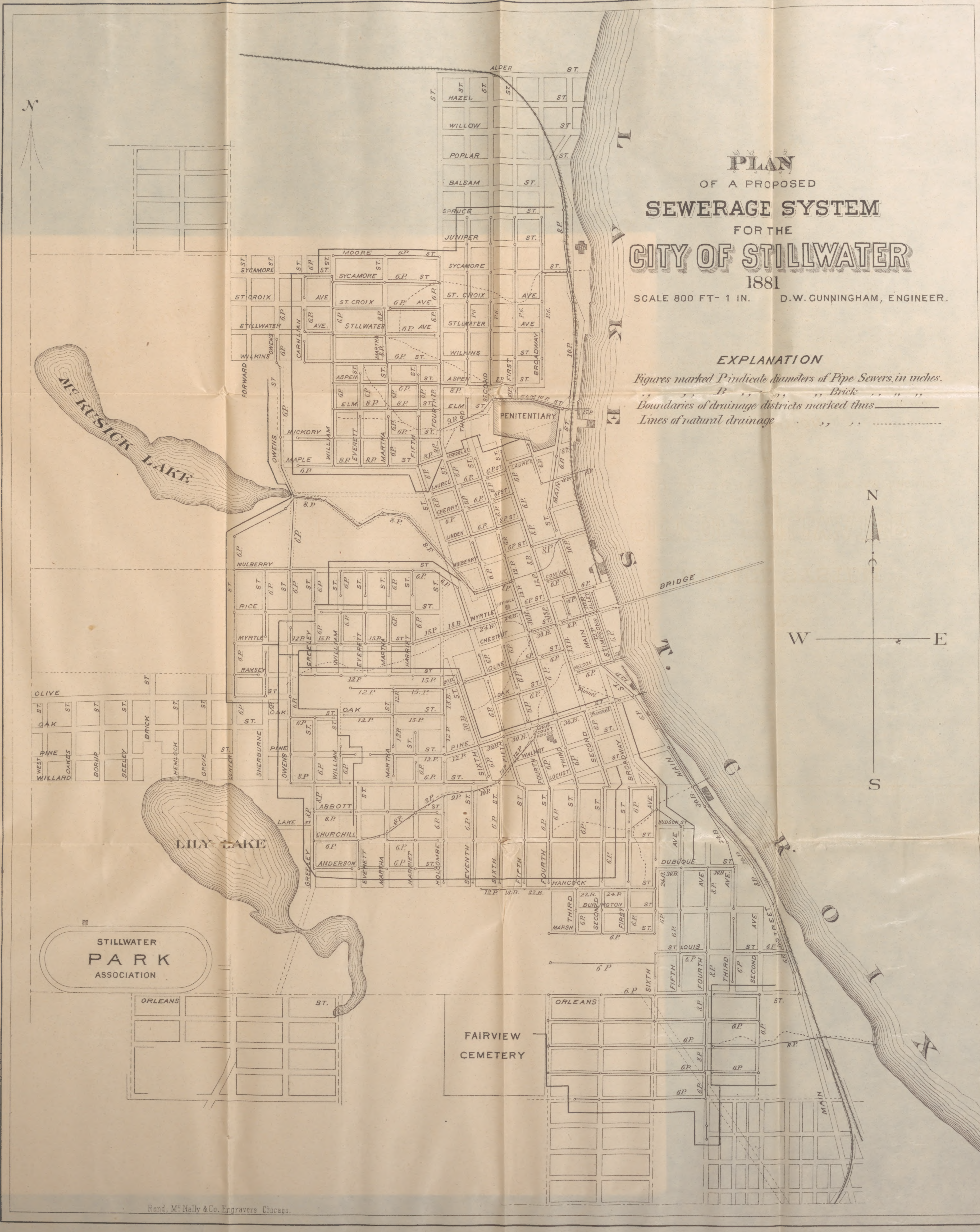
Stillwater, Minn., Sept. 1, 1881.

APPROXIMATE ESTIMATE OF COST OF SEWERS.

NAME OF STREET.	LENGTH IN FEET.	ESTIMATE OF COST.	NAME OF STREET.	LENGTH IN FEET.	ESTIMATE OF COST.
Abbott street....	1480	$ 1584	Mary street......	1160	$ 1144
Anderson street.	1450	1460	Mill Stream Val'y	3400	3310
Aspen street....	2440	3682	Mulberry street...	1610	1488
Broadway	2410	8353	Myrtle street & Union Place.	4080	7979
Center street....	1680	1636	Nelson street	 578	1539
Cherry street....	1300	1825	Oak street........	1918	2351
Chestnut street..	 720	1563	Olive street......	3205	4668
Churchill street.	1200	1267	Outlet into Lake at H. B. & B's Mill.........	 200	3095
Commercial ave.	... 300	 290	Owens street.....	4970	4926
Ct. House Ravine	2830	2900	Pine st. & Outlet.	...4180	...18011
Dubuque street..	 970	5032	Ramsey street....	2010	3546
Elm st. & outlet	3340	6490	Rice street.......	1170	1186
Everett street ...	 700	 680	School street.....	 250	 245
Fifth ave.......	1430	...1623	Second street.....	7032	...11169
Fifth street......	4470	4877	Seventh street....	1120	1008
First street	... 2398	4291	Sherburne street.	2130	2317
Fourth ave.....	1430	3482	Sixth ave........	1308	2165
Fourth street...	6330	7282	Sixth street......	2350	3848
Greeley street...	2160	2066	St. Louis street...	1050	3290
Hancock street .	2200	4846	Stimpson's alley.	 840	 822
Harriet street...	1200	1230	Third av.&Main st. connections.	2270	6706
Hickory street..	1890	1812	Third street......	6792	...10053
Holcomb street .	2000	3038	Wilkins street....	1360	1374
Laurel street....	1080	1122	Willard street....	2480	2851
Linden street ...	1060	 825	William street...	2380	2342
Main & Lake sts.	8665	...14767			
Maple street....	1950	1860			
Marsh street.....	1316	1434			
Martha street ...	... 2810	3099			
				123052	$195851
			Add ten per cent. for contingencies..............		19585
			Total............................		$215436

The above estimate includes all the sewers which will be necessary for the sewerage of that part of the whole city included between Orleans street on the southern limit; Lily Lake, Center street and McKusick's Lake on the west, and limited to the north by Wilkins street, which is included, and also including Lake street as far north as Messrs. Schulenberg, & Boeckler's mill.

Many of these sewers will not be needed for many years to come.


PLAN
OF A PROPOSED
SEWERAGE SYSTEM
FOR THE
CITY OF STILLWATER
1881
SCALE 800 FT- 1 IN.
D.W. CUNNINGHAM, ENGINEER.
EXPLANATION
Figures marked P indicate diameters of Pipe Sewers, in inches.
" " B " " " Brick " "
Boundaries of drainage districts marked thus
Lines of natural drainage " "
LAKE ST. CROIX
McKUSICK LAKE
LILY LAKE
PENITENTIARY
BRIDGE
STILLWATER PARK ASSOCIATION
FAIRVIEW CEMETERY
N
S
W
E
Rand, McNally & Co. Engravers Chicago.